OPERATION OF THE LNLS STORAGE RING RF SYSTEM

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Abstract

The LNLS storage ring RF system operates at 476 MHz and delivers up to 60 kW CW into a single RF cavity. Injection and accumulation in the storage ring are done at low energy after which the beam energy is ramped up to 1.37 GeV. Correspondingly the RF power changes from a very low initial value up to a high power determined by the amount of stored current. Several temperature and mechanical tuning control systems operate during ramping and steady state to keep the cavity tuned and away from instabilities. In this paper we discuss the results and experience obtained after more than one year of operation of the system.

1 INTRODUCTION

The light source of the Laboratório Nacional de Luz Síncrotron (LNLS) Campinas, SP Brazil has been in operation for over one year. It includes an electron linear accelerator (linac), a transport line and a booster-storage ring [1].

The storage ring has a single cell, 476 MHz RF cavity. The adjustable cavity coupling has been set at ß= 1.35. The RF transmitter uses a Philips YK 2065 klystron which can deliver 60 kW CW power into the cavity. The main RF parameters of the LNLS storage ring are listed in table 1

Frequency:	476.076 MHz
Cavity: Single cell bell shaped built by Sincrotrone Trieste.	
Effective shunt impedance:	3.4 MΩ ($P=V^2/2R$)
Unloaded Q:	41.000
Coupling:	ß=1.35
RF power:	60 kW CW
Effective cavity voltage:	480 kV
Revolution frequency:	3.216 MHz
Harmonic number:	148

Table 1 Storage ring RF parameters

Temperature of the cavity walls is controlled by water flowing through 14 parallel circuits. The water temperature is controlled by a combination of a 17 kW heater, located together with the cavity in the secondary circuit of a heat exchanger. The heat exchanger primary flow is adjusted with a controlled 3-way valve. The maximum flow in the primary is 300 l/min. and the temperature is 32 ± 0.1 °C. The water system has been designed in order to permit the cavity temperature to be adjusted between 45 and 60 °C with a thermal load of 35 kW. According to calculations, this temperature range is available for operation free of HOM instabilities, with beam currents up to 200 mA. Figure 1 shows the cavity mounted in straight section 5 of the storage ring. On the top to the left is the coaxial feed through with the adjustable coupling loop. The mechanical plunger can be seen on the right hand side of the picture and, next to it, part of the motor-driven mechanism that produces the tuning of the cavity frequency by means of longitudinal deformations of the cavity. The plunger, together with the longitudinal deformation of the cavity permits a 500 kHz tune range. Also visible are the input and output water pipes, part of the temperature control system and cooling system of the cavity. The beam entrance port is on the lower part of the picture.

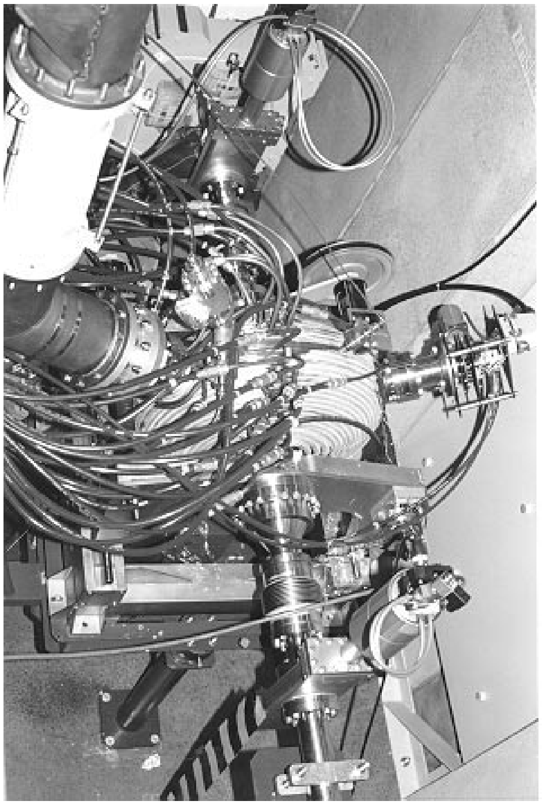

Figure 1: the cavity mounted on the storage ring

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The different parts that comprise the RF system have been described elsewhere [2]. In this paper, we will discuss the operation of the system, in particular those aspects related to low energy accumulation in the storage ring followed by energy ramping.

2 OPERATION

The RF system can be controlled and supervised from the control room during normal operations and for test purposes, from a local computer next to the transmitter area. This allows to turn on and off the different sub-systems including the high voltage power supply, adjust gap voltage and cavity to transmitter frequency difference (detune angle) and provides on-line information on interlocks and status, including cavity temperature, pressure and RF power values at 6 different locations along the transmission line: power input and output in the klystron, incident and reflected power in the circulator, incident and reflected power in the cavity and cavity gap voltage. Figure 2 shows the transmitter in the center of the ring. To the left is the rack with the low power RF electronics, tuning drivers, interlocks and computer interface systems. The cabinet on the right encloses the high-power klystron and auxiliary systems.

Figure 2: the RF panel.

The energy of the stored electron current in the LNLS storage ring varies from 120 MeV at injection up to 1.37 GeV. The operating conditions of the cavity and cooling system are very different along this large energy range. During accumulation at low energy, synchrotron radiation is negligible, beam current is rapidly varying and the beam is subjected to large synchrotron and betatron oscillations. The RF cavity parameters during accumulation are determined empirically, so as to maximize the accumulation rate. Typically, the power in the cavity is about 400 W and the effective gap voltage is 55 kV. Very little power is dissipated in the cavity walls during this phase. Thus, in order to keep the wall temperature at the set value, the temperature stabilizing system must supply 17 kW of heat to the water that flows around the cavity. Injection from the linac proceeds at about 8-10 mA per pulse until the equilibrium current is achieved. These relativily large pulses detune the cavity and drive the cavity towards the generator frequency. To avoid Robinson's instability, the cavity is detuned by several kHz during accumulation. At low energy, the cavity pressure stays in the upper 10^{-10} mbar range.

Once the low energy equilibrium current is attained, the storage ring magnets and RF power are ramped. The speed at which the gap voltage can increase is determined by 2 factors: the mechanical tuning mechanisms (axial mechanical deformation of the cavity and mechanical plunger) and the cooling capacity of the water system. Several options have been tested for the RF control method during ramping in order to rapidly increase the gap voltage, reduce the cavity temperature variations and limit the cavity detuning. Figure 3 shows the evolution of the gap voltage after a sudden variation in the voltage reference with the gap voltage feedback loop turned off.

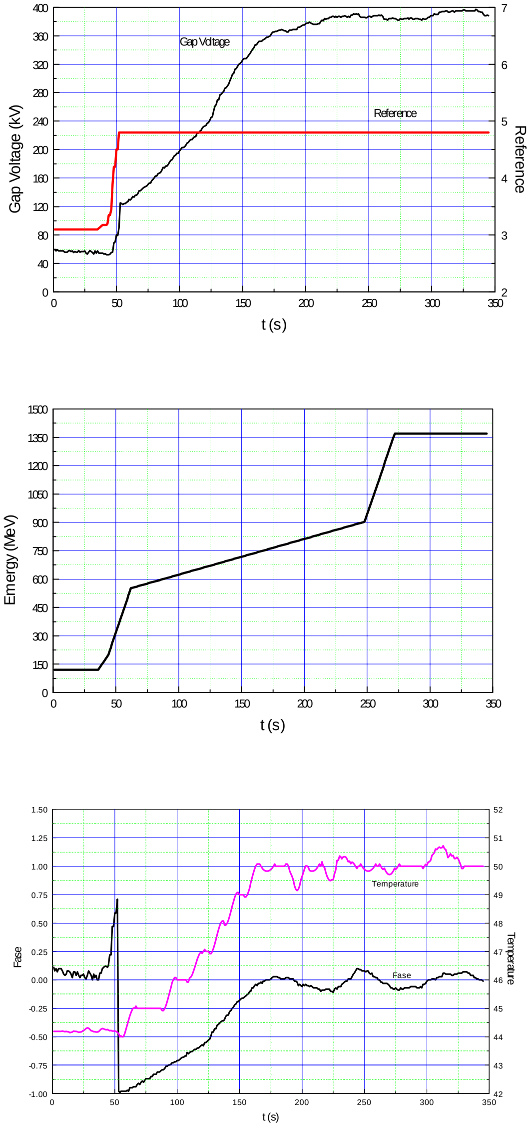

Figure 3: cavity parameter changes without feedback loop.

As can be seen, the cavity response is slow, about 2 minutes and lags behind the applied reference. In this case, a gap voltage of 200 kV is attained when the beam energy is in the 620 MeV range. The gap voltage is maximum when the energy reaches 1.1 GeV, wich is when synchrotron radiation becomes significant.

A different ramping set up is shown in figure 4. In this case, the gap control loop is on. The gap voltage reference is varied in smaller steps along the ramp and the gap voltage tracks the reference closely. Inspite of the advantage of ramping with closed loop control of the gap voltage, it is observed that low energy accumulation is more efficient when the gap voltage feedback loop is off.

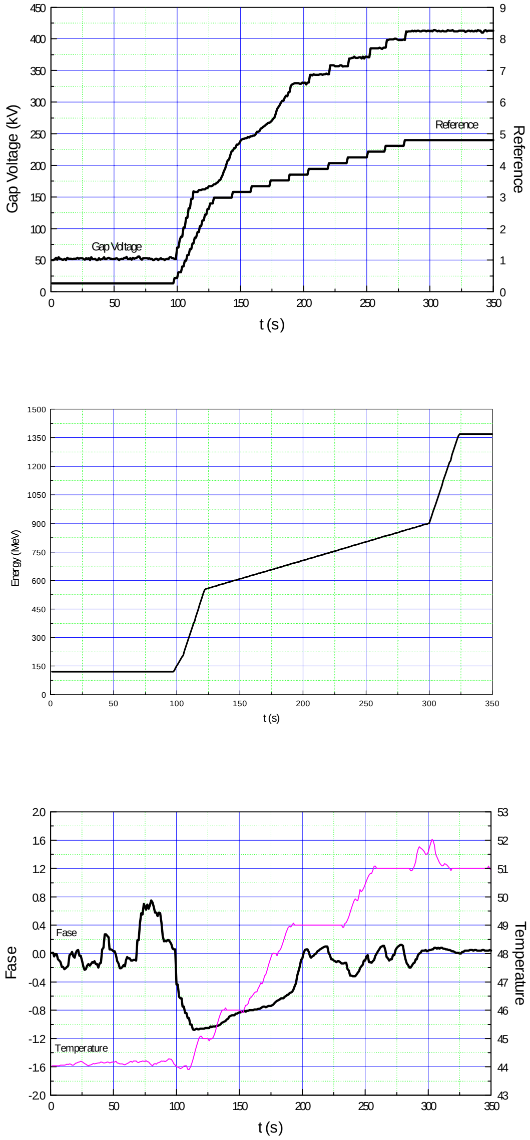

Figure 4: cavity parameter changes with feedback loop on.

At 1.37 GeV synchrotron radiation in the bending magnets amounts to 11 kW for every 100 mA. The high energy gap voltage is set at 450 kV. With this value, the beam life time is limited at present by the vacuum chamber pressure. With 50 mA of stored current, the cavity pressure stays in the high 10^{-9} level. Also at high energy, the detuning of the cavity is reduced from a large value, needed during accumulation down to 2 kHz, so that the reflected power stays low.

3 CONCLUSIONS

The LNLS storage ring RF system has been in operation for over 1 year. We have learned the operating conditions for the different beam situations: low energy injection and accumulation, RF ramping and steady final energy operation. The system has proven flexible, reliable and adequate for the machine.

REFERENCES

[1] A. R. Rodrigues et al. ìLNLS Commissioning and Operationî. In these proceedings.

[2] D. Wisnivesky et al. ìThe LNLS RF Systemî. Proceedings of the 5th European Particle Accelerator Conference EPAC 96, p. 2038, 1996.